

Spacial Patterns of Fine Root Abundance in Mixed Larch-Ash Plantation

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Abstract Horizontal and vertical distributions of fine root abundance (mass per unit ground surface area) were investigated in a densely planted larch - ash -stripe - mixed forest on dark brown forest soil in northeast China. There was evidence for some degree of below-ground niche partitioning (or differentiation) between the two species in both the horizontal and vertical directions. The ash fine roots largely penetrated into the larch belt (larch sub-community) in surface soil (0-20 cm), indicating a possible inductive effect of larch ecological field on ash roots; while the penetration of larch fine roots into ash belt (ash sub-community) was much restricted, which reflected a negative influence of ash ecological field on larch roots. In the vertical direction of marginal soil, the ash fine roots were mainly distributed in topsoil with a vertical gradient similar to that as in the internal ash sub-community, but the larch fine roots were relatively compelled to deeper soil layers by the competition (or exclusion) of marginal ash trees. All the differences or complementarity were considered to the result of inter-specific competition, which was important to the coexistence of the two forest species and the sustainability of mixed plantation.

Key words: *Larix olgensis*, *Fraxinus mandshurica*, Mixture plantation, Fine roots, Spacial distribution, Interspecific difference

Introduction

For nutrient and water seeking, fine roots represent a functionally important part of the biomass of forest trees. In forest stands, where fine roots are densely packed in surface soil, strong competition for nutrients and water may be expected among rootlets and mycorrhizas of neighboring tree individuals. This was evidenced by various trenching and plant removal experiments (cf. Grub 1994). To reduce exploitation competition, spacial and / or temporal separation of the root systems and their activities is likely to occur in multi-species communities. Some researchers (e. g. Klisz et al. 1987; Volker and Christoph 1994) have reported differences in vertical and horizontal distribution of fine root abundance and fine root density of coexisted species in mixed forests.

This paper reports on a study that examined the horizontal and vertical distribution of fine root abundance (mass per unit ground surface area) in a mixed larch(*Larix olgensis*)- ash (*Fraxinus mandshurica*) plantation in northeast China. The main aim of our study was to characterize possible interspecific differences in the vertical and horizontal distribution of fine roots in a shared soil volume, which having long been supposed to be a mechanism of the superiority of *L. olgensis* - *F. mandshurica* mixed plantations. The study was also part of an investigation into interspecific dif-

ferentiation in nutritional behavior (i. e. spacial, temporal, quantitative and chemical aspects of nutrient uptake) between forest tree species.

Site and Methods

A mixed stand of larch (*L. olgensis*) and ash (*F. mandshurica*) was selected in the northern part of the Changbai Mountains of China (127°30' E, 45°20' N). Larch and ash were stripe-mixed (12 rows of larch with 12 rows of ash), 12 years of age, and 3600 hm² in stem density. Both the larch belt and the ash belt had closed completely when conducted the research in 1995. Located down slope, the site had a thick fertile soil (Dark Brown Forest Soil) without significant difference in solum thickness (which may essentially influence the vertical distribution of fine roots). Because the stand was of wide-belt-mixed, so the larch belt and the ash belt could be considered as "larch sub-community" and "ash sub-community" respectively, while the mid line between two belts (stripes) was just the border of two sub-communities.

To study the vertical distribution of fine roots of both species, 3 sequences of soil profile (9 profiles per sequence, 30×30 cm each profile) were sited along the border line between two sub-communities, 3.5m line in internal larch sub-community, 3.5m line in internal ash sub-community respectively (Fig. 1). Each profile was

divided into 6 depths (0-10, 10-20, 20-30, 30-40, 40-50, 50-60 cm). Soil sample of 9000 cm³ volume at each depth was taken and the live fine roots (less than 1 mm in diameter) of larch and ash were carefully separated

by hand. Fine root samples were cleared in water, dried at 105 °C, and then weighed. Dry mass was expressed in terms of root abundance. Statistical calculations for 3 sequences of profile were made respectively.

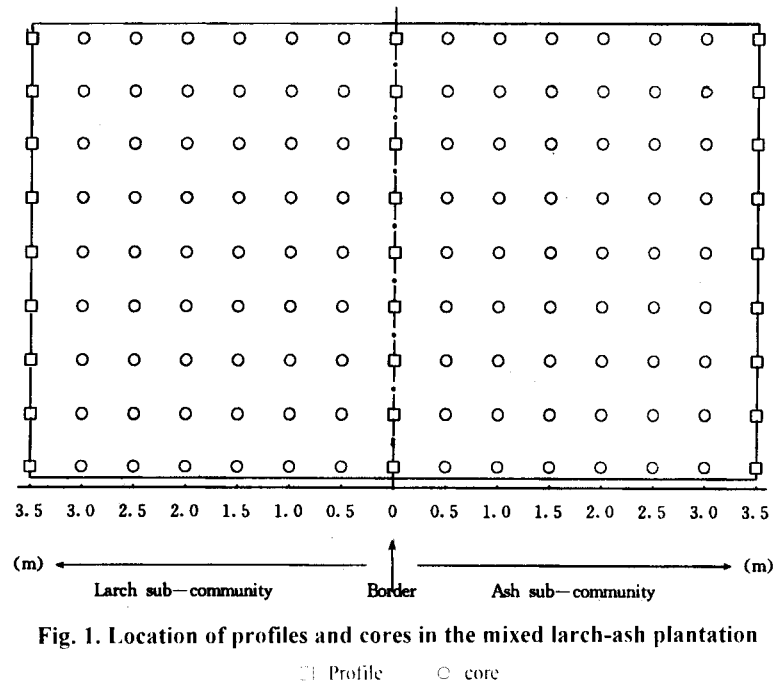


Fig. 1. Location of profiles and cores in the mixed larch-ash plantation

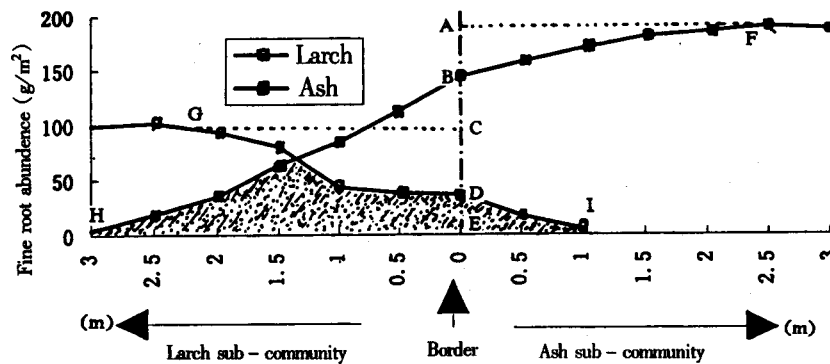


Fig. 2. Horizontal distribution of fine root abundance for larch and ash in surface soil (0-20 cm) in the vicinity of sub-community border. Data are means of 9 profiles or 9 cores.

In addition to the 3 sequences of profiles mentioned above, 12 sequences of cores (9 cores per sequence, each core 5 cm in diameter) were sited at intervals of 0.5 m (Fig. 1), in order that the horizontal distributions of fine roots of both species in surface soil (0-20 cm) could be characterized. The extraction method of fine root in cores was similar to that as described above for profile samples. Data were statistically calculated according to profile /or core sequences (i. e. distances from border line).

Result and discussion

Horizontal distribution

In the vicinity of sub-community border, the extending behavior of absorbing roots (live fine roots less than 1 mm) of larch and ash trees characterized the two species' horizontal differentiation in absorbing sphere. Ash fine roots penetrated into the larch sub-community to a distance of about 3.0 m (approximately 3 times of crown dimension), at which the abundance of ash fine

roots was still significant (Fig. 2). However, a mere 1.0m into the ash sub-community was almost beyond the reach of larch fine root distribution, where the larch fine root abundance had rapidly reduced to a minute value (Fig. 2). Thus, the intermingling area of fine roots of both species mainly fell in the larch sub-community (Fig. 2). This horizontal pattern of fine root distribution reflected a horizontal aspect of underground niche overlap or niche differentiation of the two species. The cause of the differentiation can be explained as the following: (1) *F. mandshurica* had well developed root system, and ash root was much competitive than larch root; (2) The chemi-ecological field of larch trees might have a inductive effect on ash roots (Guo Qinxu 1991; Wang Yihong et. al. 1994); (3) On the contrary, the chemi-ecological field of ash trees might be exclusive to larch roots, which restricted the extension of larch root to ash sub-community.

The ash fine root abundance exhibited gradual declination from a 2.0 m distance (in ash sub-community) to the border or larch sub-community (Fig. 2). This is considered to be mainly a consequence of the ash-tree-density-field weakening at its sub-community edge. In larch sub-community the larch fine root abundance showed a more rapid decrease from an opposite 2.0m distance (in larch sub-community) towards border or ash sub-community (Fig. 1), which was attributed not only to the larch-tree-density-field weakening, but also to the interference from ash trees. As illustrated in Fig. 2, the geometrical area (which will be marked as "S" in the following discussion) under the fine-root-abundance curve can be used as a indicator of fine root amount. For *F. mandshurica*, S_{III} indicates the decrement of fine root amount caused by the weakening of ash-tree-density field, S_{BEH} represents the increment resulted from the penetration into larch sub-community, $S_{BEH} > S_{III}$, indicating a net increase in fine root amount of marginal ash trees in this mixed plantation. Some researchers have reported a stimulated growth of *F. mandshurica* when stripe mixed with *L. olgensis* (or *L. gamelinii*) (Zhou Xiaofeng 1986; Guo Qingxi 1991; Wang yihong et al. 1994), of which the mechanism can be partially explained with the result of our study. As to *L. olgensis*, the decrement of fine root amount (being attributed to the weakening of larch-tree-density field and the concurrent intensification of chemi-ecological field of ash trees) can be represented by $S_{C \cap D}$, while the increment (owing to the restricted penetration into ash sub-community) can be expressed as S_{DEF} , $S_{DEF} < S_{C \cap D}$, means that the absorbing roots of marginal larch trees were largely out competed from the surface soil (0-20

cm), and that the edge effect on larch tree growth might be negative. However, previous studies have pronounced no essential negative impact on the growth of larch trees in larch-ash mixed plantations (Guo Qingxi 1991; Chen Zhiguo 1991; Wang Yihong et al. 1994), and our investigation of the research site just proved a positive rather than negative effect on marginal larch trees in respect of above-ground growth. This growth paradox (i. e. larch fine roots were under-represented in the fertile surface soil when taking into account a even stimulated above-ground growth) implicated a much efficient exploitation of the deeper soil volume by marginal larch trees, which was just ascertained by the following studies on vertical distribution of fine roots.

Vertical distribution

The soil volume in the immediate vicinity of sub-community border is considered to be a co-exploited space for marginal larch and ash trees, where the vertical patterns of fine root distribution can best reflect the below-ground niche overlap or niche partitioning in vertical direction between the two coexisting species. Investigation result of vertical distribution of fine root abundance for both species at the sub-community border is shown in Table 1 (column 2 and column 3), together with that for larch and ash in its internal mono-specific sub-community (column 1 and column 4). For the convenience of making a multiple comparison of vertical rooting patterns, the absolute values in Table 1 are converted into relative data in terms of proportion (percentage) in total abundance of fine root in the whole profile (0-60 cm), as shown in Fig. 3.

Table 1. Vertical distribution of fine root abundance for larch (*L. olgensis*) and ash (*F. mandshurica*) under different community conditions (Fine root abundance, g/m²)

Soil layer (cm)	<i>L. Olgensis</i> in internal larch sub-community (g/m ²)	<i>L. Olgensis</i> at border of two sub-communities (g/m ²)	<i>F. Mandshurica</i> at border of two sub-communities (g/m ²)	<i>F. Mandshurica</i> in internal ash sub-community (g/m ²)
0 — 10	65.39±17.26	19.18±4.31	87.33±12.13	126.34±20.96
10 — 20	28.81±8.62	17.33±4.77	56.50±9.38	63.43±14.57
20 — 30	14.56±3.71	18.86±4.36	28.81±6.21	39.20±6.88
30 — 40	5.23±2.13	11.21±3.24	9.64±3.00	18.16±5.19
40 — 50	6.44±1.78	8.75±2.06	5.92±1.69	10.53±2.84
50 — 60	2.18±1.36	12.49±3.67	5.44±2.50	2.68±1.31
Σ	123.70±19.89	87.82±9.41	193.64±17.08	260.34±27.12

There existed considerable difference between *L. olgensis* and *F. mandshurica* in respect to the vertical exploitation of absorbing sphere in a shared soil volume

of the sub-community border, for their fine root vertical distribution curves separated from each other very clearly (Fig. 3, D), i. e. the ash fine roots mainly concentrated in superficial layers (0-20 cm), while the larch fine roots relatively increased in deeper layers (below the depth of 20 cm). This vertical rooting pattern represented a vertical aspect of under-ground niche differentiation, which was favorable to reduce exploitation competition between the two species. Here, at the sub-community border, the difference in fine root vertical distribution between the two species is considered to be a consequence which the marginal larch trees had altered their inherent rooting behavior (as performed in the internal larch sub-community) under the influence of chemi-ecological field of marginal ash trees (Fig. 3, C), while the marginal ash trees kept their

original rooting habit without pronounced change compared with that growing in the internal ash sub-community (Fig. 3, B). It can be expected that ash is the superior competitor for superficial soil when mixed with larch; and for larch, though being excluded in upper layers of soil, but its root system is more variable and more adaptable to the deeper soil environment, which help to offset the impact of superficial exclusion by ash. In addition, it should also be noticed that, in monospecific sub-community, larch and ash performed much similar in vertical rooting pattern (Fig. 3, A), suggesting that either a tree species is "shallow-rooted" or "deep-rooted" should not be arbitrated irrespective of community and / or soil conditions.

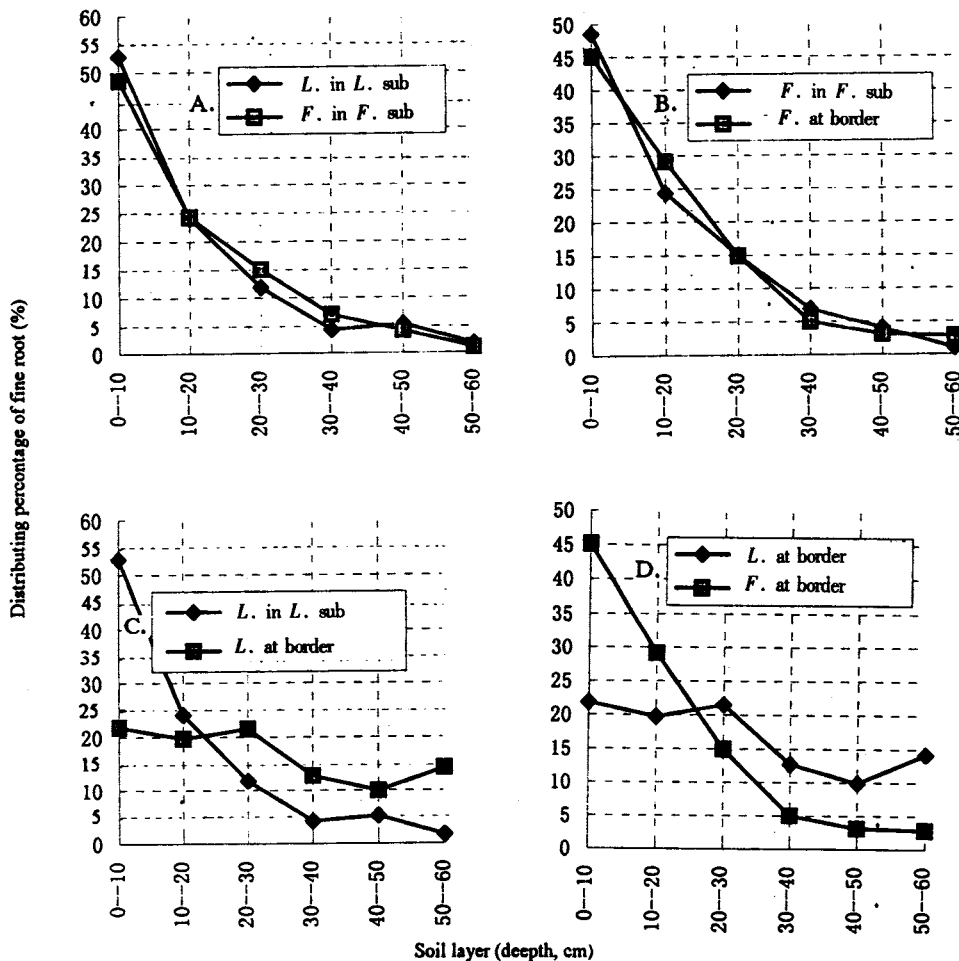


Fig. 3. comparison of vertical distribution of fine root (<1 mm) for *L. olgensis* and *F. mandshurica* growing at different community position.

A: ◆ *L. olgensis* in internal larch sub-community. ■ *F. mandshurica* in internal ash sub-community. B: ◆ *F. mandshurica* in internal ash sub-community. ■ *F. mandshurica* at the border of two sub-communities. C: ◆ *L. olgensis* in internal larch sub-community. ■ *L. olgensis* at the border of two sub-communities. D: ◆ *L. olgensis* at the border of two sub-communities. ■ *F. mandshurica* at the border of two sub-communities.

In theory, close to the sub-community border is a place where the intensity of tree-density filed of each species is only half of that in its internal monospecific sub-community, and consequently, here the total abundance of fine root of fine root (in 0-60 cm profile) for each species should also be an approximation of 50% of the internal value if there weren't edge effect. However, the practical total abundance (in 0-60 cm profile) for larch and ash in the marginal soil volume were 87.82 g/m² and 193.64 g/m² respectively (Table 1), nearly made 71% and 74% of the values as in relevant internal sub-communities, which implicated a mass increase of fine roots of marginal larch and ash trees. Further, the increase in fine root biomass of both marginal larch and ash trees also indicated a raised utilization efficiency of the two-species-shared marginal soil volume. Let us suppose that the utilization efficiency of soil volume (0-60 cm profile) are all 100% in the internal larch and internal ash sub-communities, then the marginal soil volume utilization efficiency should be 145% (71% for larch plus 74% for ash) in terms of fine root abundance ratio. This has given a mechanism explanation of the superiority of larch-ash mixed stands.

References

- Büttner, V. and Leuschner, C. 1994. Spatial and temporal patterns of fine root abundance in a mixed oak-beech forest. *For. Ecol. Manag.* 70(1/3): 11-21.
- Ford, E.D., and Deans, J. D. 1977. Growth of Sitka spruce plantation: Spatial distribution and seasonal fluctuations of lengths, weights and carbohydrate concentrations of fine roots. *Plant and Soil.* 47: 463-485.
- Kalisz, P. J., Zimmerman, R. W., and Muller, R.N. 1987. Root density, abundance, and distribution in the mixed mesophytic forest of Eastern Kentucky. *Soil Sci. Soc. Am. J.* 51: 220-225.
- Moir, W. H. and Bachelard, E.P. 1969. Distribution of fine roots in three *Pinus radiata* plantations near Canberra. *Ecology.* 50: 658-662.
- Persson, H. 1980. Spatial distribution of fine-root growth, mortality and decomposition in a young Scots pine stand in Central Sweden. *Oikos.* 34:77-87.
- Roberts, J. 1976. A study of root distribution and growth in a *Pinus sylvestris* L.(Scots pine) plantation in East Anglia. *Plant Soil.* 44:607-621.

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